USING SOLAR POWER TO PUMP WATER FOR LIVESTOCK IN MONTANA

Conservation Districts Bureau

Montana Department of Natural Resources and Conservation
1520 East Sixth Avenue
Helena, Montana 59620-2301

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May, 1994

ACKNOWLEDGMENTS

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Note to Readers

This publication was prepared by the Montana Department of Natural Resources and Conservation for the benefit of persons interested in the use of photovoltaic systems to pump water for livestock. The information covered is intended to demonstrate the general capabilities of such systems, but is by no means exhaustive. Several of the projects discussed here were funded by the Conservation Districts Bureau to present this emerging technology and encourage the use of renewable resources.

Technology continues to advance the capabilities of all the various kinds of remote water pumping systems, and potential purchasers will want to do some research to determine the best way to meet their needs. Nothing in this publication is intended to imply endorsement of any particular system or supplier of equipment.

COVER PHOTO: *George Morella and Cory Swenson with Morella's sun-tracking solar panels near Broadus*

CONTENTS

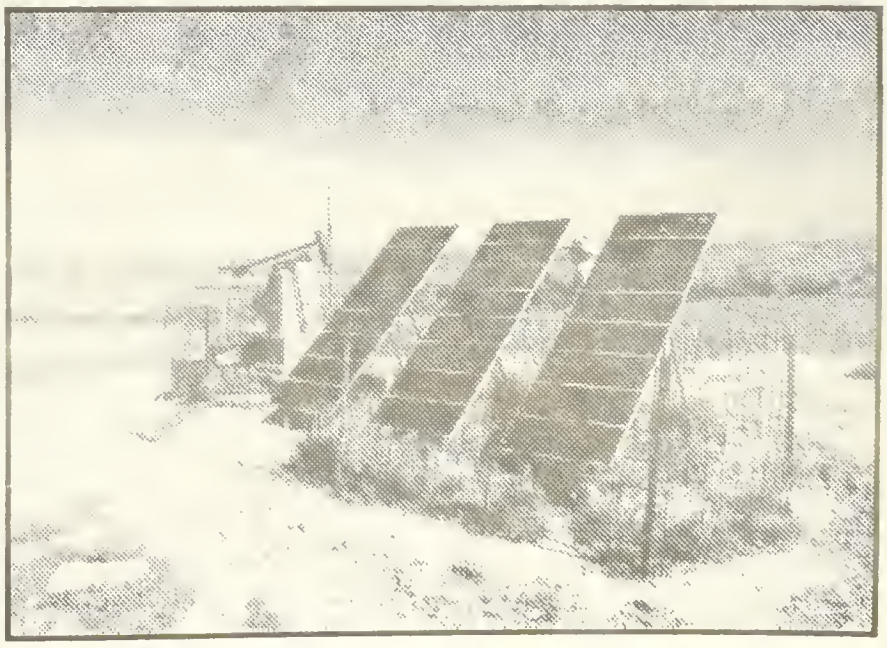
INTRODUCTION TO SOLAR-POWERED STOCKWATER PUMPING

Two things are certain in Montana's cow and sheep country in the summer: the sun will shine, and cows and sheep will need a drink of water. These two facts balance each other nicely when the sun's energy is used to pump water for thirsty critters.

The use of solar power to pump stockwater has been slow to take off in Montana, but has established a good track record after at least 10 years on the scene. Tom Bishop, Sales Engineer for Sunelco, a solar equipment firm in Hamilton, said his company alone has installed over 200 solar-powered stockwatering systems in Montana since beginning business in 1985. Several other firms, including SUNCRAFT of Bozeman, Western Pump in Park City, and KAL-Well Service in Laurel, have installed at least two dozen more.

Solar Equipment Becoming More Adapted

At the beginning, pumps and other equipment sometimes were not specifically designed for solar operation, and had to be adapted. Nowadays, however, a wide variety of equipment specifically designed for use with solar panels is available to meet certain needs, such as pumping a particular amount of water in a given location. Some solar-powered pumps can push water up to 1,000 feet above the source.



THE EQUIPMENT

Solar-powered pumping equipment usually consists of three main components: solar panels, an electronic controller, and the pump. Solar panels come in a wide range of sizes and costs. Either they can be mounted in a non-moving bracket faced to obtain the most sunlight available to a non-moving system, or they can be mounted in a tracking mount that automatically pivots to follow the sun. This tracking operation is accomplished by the action of sunlight on Freon that is sealed into the tubular framework of the mount. Freon vaporizes in the portion of the tubing that is warmed by the sun and condenses in the cooler portion on the opposite side. The mount is designed so that the weight of the heavier, condensed Freon tilts it toward the sun. The panels are automatically faced toward the sun from sunrise until sundown. This mechanism is reliable and usually trouble-free. Depending on the season, the sun tracker can increase the solar power available to a particular system by 25 to 40 percent.

Panel Wattage Varies

Most modern panels produce 60 to 64 watts each. Most pumps require a minimum of 120 watts. The total wattage (and number of panels) needed for any particular pumping application depends on how much water is to be pumped, how high it is lifted, and how fast.

Electronic controllers have been pretty much standardized for solar uses, and usually are trouble-free. Their primary purposes are to protect the pump and produce more water in low light levels. For example, at first light in the morning, the solar panels will produce full voltage, but low amperage. If the pump operates under these conditions, it can be damaged or destroyed. The function of the controller in this situation is to trade voltage for amperage to start the pump and then slowly increase the voltage as sunlight levels increase. A second function of the controller is to shut the pump off when a float switch signals a water tank is full. The controller also can be equipped to shut the pump down if the water level should drop to a preselected level in the well, to protect against running the pump dry.

Wide Variety of Pumps Available

Pumps come in many types and sizes to meet specific needs. The cheapest of these, and in some ways perhaps the most reliable and handy for farm/ranch operations, is the diaphragm-type submersible pump. The weak portion of this pump is the diaphragm, which eventually will fail. Such failure is likely to occur after about four years. On the other hand, this pump design is being continually improved, and even in 1993, it is possible for a rancher or other user to replace the diaphragm in some models "with a screwdriver on the tailgate of a pickup," according to Tom Bishop. Rebuild kits that are currently available cost about $100. Anyone owning a pump of this type could get maximum reliability by routinely rebuilding it every second year. "Do that, and you can just about forget about it," Bishop said. Diaphragm pumps also are highly efficient.

More Money, More Durability

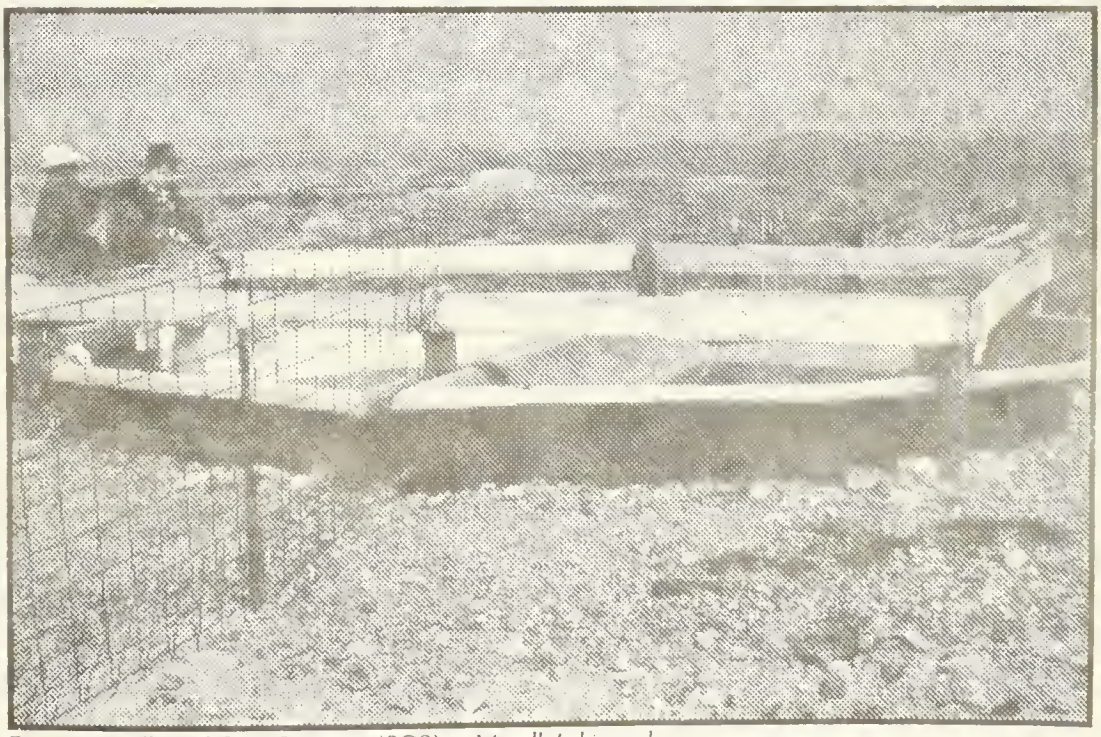
A second type of pump is the centrifugal submersible pump. These pumps start out about three times as costly as diaphragm pumps, but last longer with less attention. The rebuild interval on such pumps normally is about every 10 years. Direct current centrifugal submersible pumps of the type used in solar systems are basically the same as the conventional alternating current pumps, which are in universal use for pumping water from wells, and share the same reputation for reliability.

Also, centrifugal submersibles usually have a built-in electronic controller, eliminating the need to purchase a separate unit. Several lower cost versions of this pump type are currently in development. When these come on the market, they may be one of the most practical options.

Most Efficient, Most Reliable

The most efficient and most reliable solar-powered pump is the jack pump type. This type operates in a well with a drop pipe and a sucker rod, much like the pumps used by windmills or similar pumps operated with conventional electricity.

Other types of pumps are available for special applications. George Morella of Broadus uses a piston pump to meet watering needs in a 3,000-acre pasture (see page 6 for a discussion of Morella's system).



George Morella and Cory Swenson (SCS) at Morella's big tank

OPERATING CONDITIONS AND CONSIDERATIONS

Solar-powered pumping systems are not cheap. Neither is any of the alternatives. Windmills are subject to breakdown and don't operate when the wind doesn't blow. Pumps fired by gasoline or propane are sometimes unreliable and "a pain in the neck", besides being expensive. Any of these options is cheaper than running an electric distribution line into a remote area. The charge for extending electric service ranges from $6,000 to $25,000 a mile.

Installation

Many farmers and ranchers have installed their own solar pumping systems, using instructions furnished by the equipment supplier. In the case of non-tracking systems, it is important that the panels be installed to face due solar south, which in Montana ranges from about 12 to 20 degrees east of magnetic south, increasing with distance to the west. Even ranchers of long experience can be wrong about the location of south on their ranches. Systems installed by "eyeball" in Montana have been up to 45 degrees off. Equipment suppliers can tell purchasers how to face the panels correctly.

"In the case of non-tracking systems, it is important that the panels be installed to face due solar south, which in Montana ranges from about 12 to 20 degrees east of magnetic south, increasing with distance to the west."

Reliability

Reliability is a serious concern for stockmen. Stock cannot be left without water. In general, solar systems are as reliable as any other system. Though such systems normally can be relied upon to function without attention for extended periods of time, no rancher is going to let more than three days pass without checking the stockwater. Tom Bishop of Sunelco said the systems his company designs normally include at least three days water storage. This provides insurance against periods of low sunlight, and keeps the stock watered for at least a short period in the case of equipment failure.

System Backup

About the only way to protect against pump failure is to have a spare pump on hand, or to keep a rebuild kit handy for pumps that allow easy rebuild.

The solar panels, although made of glass, are more durable than might generally be thought. Panels are designed to withstand winds of 125 mph and golf-ball-sized hail with winds up to 52 mph. Vandalism of panels, which comes immediately to mind, is pretty rare, according to Bishop. For one thing, panels normally are located in remote ranch areas, well away from most vandals.

Premature mechanical failures, such as breaking of drive belts or parting of cables in jack pumps, normally are caused by misadjusted components, Tom Bishop said. Such problems can be avoided by using care in installation or adjusting components properly during operation.

Versatility

A major advantage of solar water pumping systems is the versatility they offer. For example, some ranchers mount solar panels on a trailer and then move the trailer from a pump in one pasture to a pump in another. The pumps don't necessarily have to be the same type, as long as they can operate on the power available from the panels. The panels also can be used to charge batteries. When a solar system is applied to a poorly producing well, part of the energy from the panels can be used to charge batteries to operate the pump at night. This allows the operator to make maximum use of low production wells. Use of batteries does require more panel capacity than would be needed just for pumping during the sunlight hours, however.

The presence of a reliable stockwater pumping system in remote areas often enables the ranch operator to get better use out of the range. For example, the ability to distribute water to various portions of a large pasture often allows cross-fencing and implementation of a rotation grazing program. Ranchers familiar with the capabilities of solar water pumping often come up with their own ideas of how it could be applied to their particular situations.

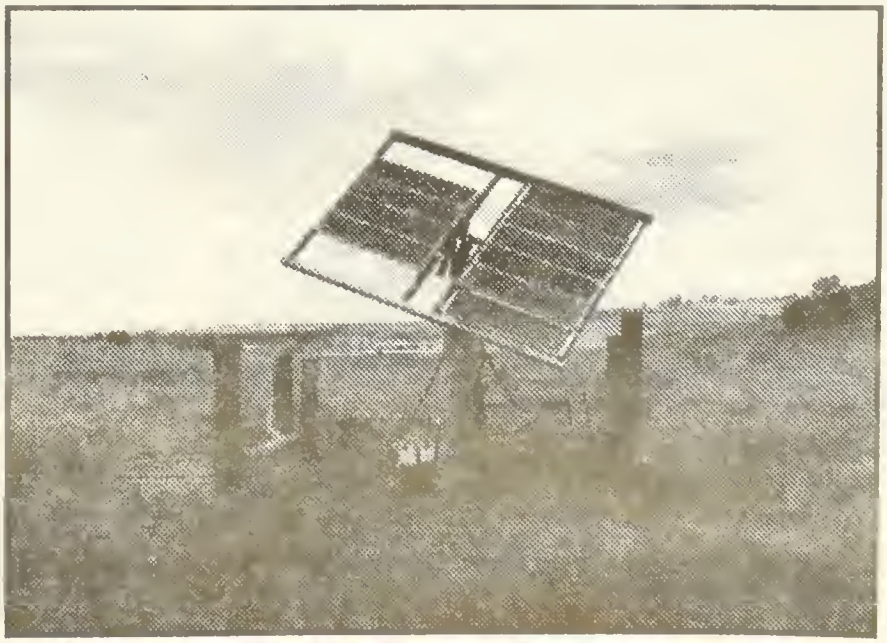
Cost

Solar systems are not cheap, but generally are competitive with other types of systems. A solar water pumping system can cost $2,000 or more. Costs rise as systems get more elaborate, as wells get deeper, and as more water is needed. Water pumping systems come in different grades, from relatively low cost on up the scale. The more expensive the system, the better service it is expected to provide, particularly reliability. Lower cost systems will meet most requirements, but may require more service than the more expensive models.

Warranties

Almost all solar water pumping equipment is covered by the manufacturer's warranty. Warranties on solar panels normally are for 20 years, 10 years on the sun tracking mechanism, and one or two years on pumps.

"A major advantage of solar water pumping systems is the versatility they offer."



One of Phil Fox's systems

REPORT FROM THE FIELD

GEORGE MORELLA, BROADUS

270-Foot Lift From One Solar Horsepower

George Morella of Broadus has been using solar power to water his cattle since 1990. "I never touch that thing at all," George said, referring to the array of twelve 48-watt solar panels that power his 1-horsepower water pump.

Morella's pump lifts water 270 feet from an artesian well to a 4,500-gallon storage tank on a hilltop a mile and a half away. From this large tank, water is gravity fed to three 1,000-gallon tanks located in three different pastures. The farthest of these tanks is nearly three miles from the well. The entire pasture area served by the pump is 3,000 acres.

Solar Power Makes Grazing System Possible

Before Morella had the solar system installed, the 3,000-acre pasture was one big unit with only one stockwatering location, at the well on the south edge. This lack of water limited the use of the pasture because cattle would not graze any farther from water than they had to. This also caused overuse of the pasture near the water. Along with development of the solar pumping system, Morella fenced the pasture into four units, each with its own water supplied by the pump.

"I ran about 75 head in there before," Morella said . "Now I can run up to 100."

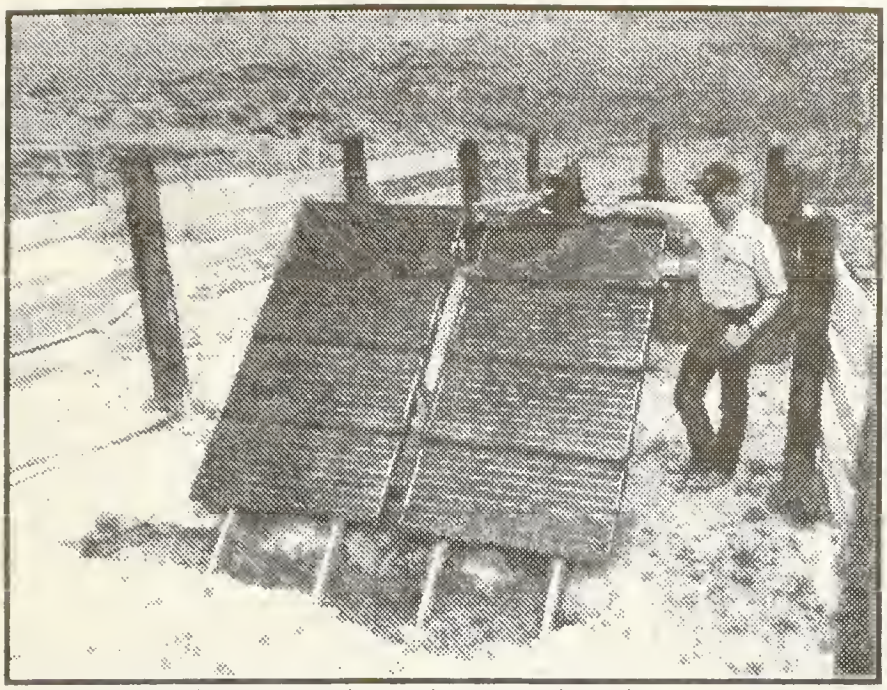
Morella said that, in full sunlight, the system can pump up to 4 1/2 gallons per minute to the storage tank. That's 270 gallons an hour over long summer days, adding up to a substantial amount of water. Morella's panels are mounted on a sun-tracking carriage, which maximizes the amount of sunlight that can be used in a given day.

"I ran about 75 head in there before...now I can run up to 100."

Turns on in April and Runs All Season

Morella was enthusiastic about the low maintenance his system requires. He checks the system every third day, just to make sure the cattle have water. Other than that, he said, "I come up and turn her on in April, and she runs until I shut her down in October." The system is not entirely flawless, however, and Morella initially had to replace a drive belt on the pump about every six weeks. This problem was later remedied with a simple adjustment. Another worry is the proximity of the solar panels to the highway. The use of firearms for vandalism is not unknown in eastern Montana, and potshots could destroy the panels. So far, however, no problems of this type have arisen.

"Solar is the way to go," Barnaud said. "There aren't many moving parts. Windmills are nice, but they break down."



Cory Swenson with stationary solar panel mount on the Earley Ranch in Powder River County

BERNARD BARNAUD, BROADUS

More than 1,900 Gallons a Day with Sun Power

Some distance outside of Broadus, Bernard Barnaud of the Earley ranch is happy with his solar-powered pumping system after two years of service. This system uses a jack pump, similar to the familiar oil field pumps, with a packing gland for forcing water uphill from the pump. The system is designed to pump water against a "dynamic head" up to 280 feet—"dynamic head" referring to the total resistance to be overcome by the pump, including friction in the 1.5-inch pipe. The well for this system is 160 feet deep.

Water for 100 Cow/Calf Pairs

The pump moves water up 80 feet of elevation from ground surface at the well to a 4,000- gallon tank 3,800 feet away. This tank, along with a 1,000-gallon tank at the well, can provide enough water for up to 100 cow/calf pairs. In eight hours of pumping in full sun, the pump can provide up to 1,920 gallons of water. In reality, the pump normally operates longer than this each day.

The pasture served by the system is fenced into four separate units, making it possible to implement a rotation grazing system. Previously, a windmill provided water for the upper pasture where the 4,000-gallon tank is located, but there was no grazing system.

The system uses eight solar panels in a stationary ground-level mount. For maximum efficiency, stationary solar panels should face due south, but the panels on the Earley ranch were accidentally faced at least 30 and maybe 45 degrees east of south. "We just eye balled it in where we thought south was," said Cory Swenson, an SCS range conservationist who helped with the installation. The panels subsequently were moved to face south, improving efficiency, Swenson said.

In its first two seasons, the system has been generally reliable, although there was a problem with breakage of a cable that is part of the assembly that lifts water up the well casing. This problem was believed to be caused by a misalignment in the system and was expected to be readily remedied.

"Solar is the way to go," Barnaud said. "There aren't many moving parts. Windmills are nice, but they break down." And, he might have added, sometimes the wind does not blow.

HAROLD JENSEN and DALE SCHWIEGERT, BAKER

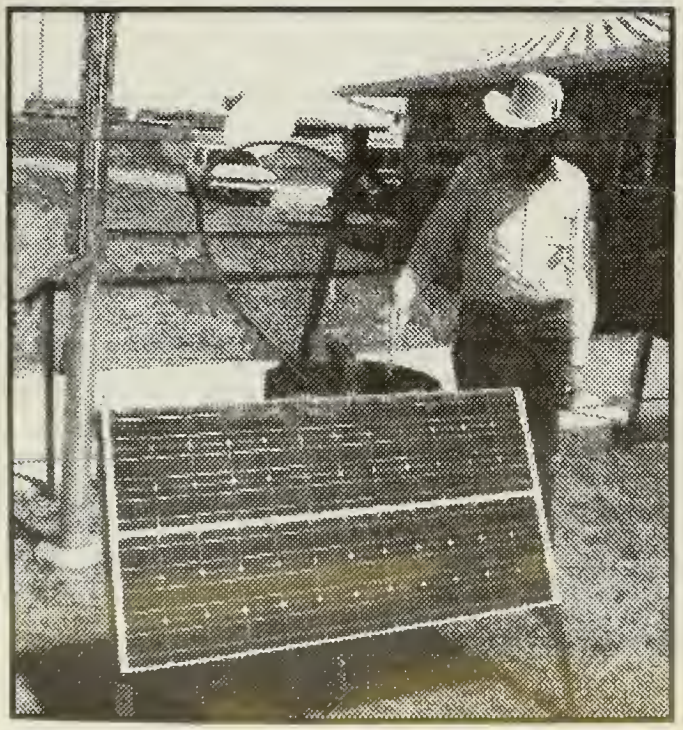
Water Near Surface Ideally Suited for Solar Pumping

At Baker, the local conservation district has been experimenting with a set of two portable solar panels to determine the feasibility of solar water pumping in this area.

Harold Jensen, formerly a supervisor of the Little Beaver Conservation District at Baker, is enthusiastic about the potential of solar power for pumping stock water. "They have a lot of advantage over windmills," he said.

Near-Artesian Wells Fine for Solar Pumps

In the Baker area, many wells are close to being artesian, with the water rising in the casing to a level not far below ground surface. For this situation, a nonsubmersible pump that fits inside the well casing above the water level performs adequately. A pump of this type connected to the district's two 60-watt panels was tried under various conditions and worked well, surpassing the performance of windmills "up to a point," as Jensen said.



Harold Jensen with portable demonstration solar panels and pump in Baker.

Bad Water Stops Pump

The "point" in this case was the point where the pump failed because of contaminated water. Much of the groundwater around Baker is naturally high in salts and other natural compounds, presenting a tough challenge for some pump types to operate over the long term. Persons considering pumping such water should check the warranty on any pump they might purchase. These nonsubmersible, in-the-casing pumps also are applicable to developed springs. They must be placed no more than 20 feet above the surface of the source water. They also have very close tolerances and cannot tolerate silt or other impurities in water. Other systems can safely handle such conditions.

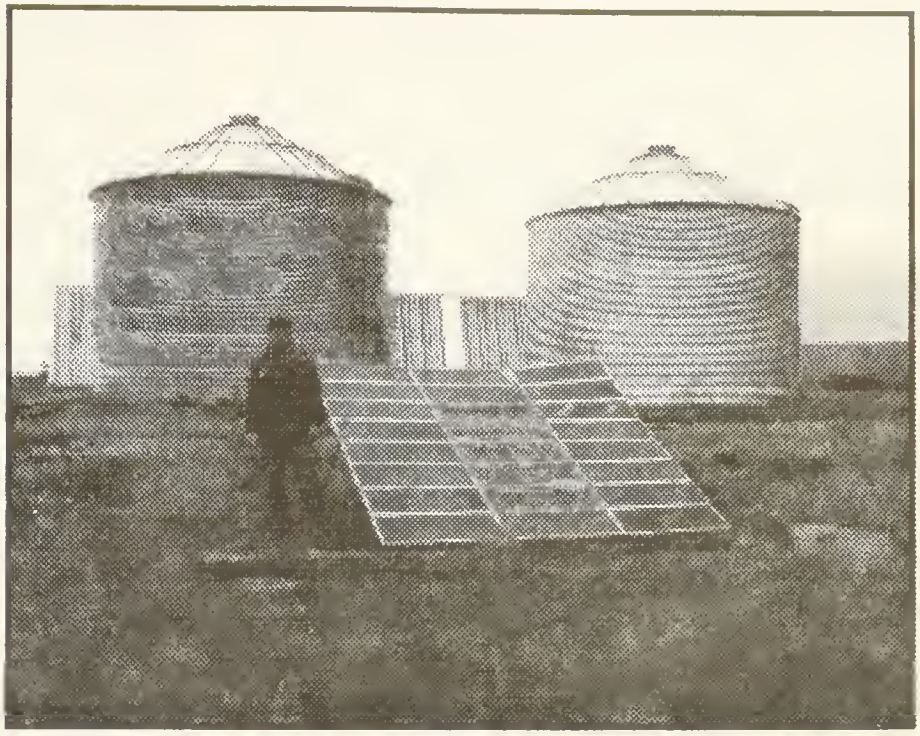
"Persons considering pumping such water should check the warranty on any pump they might purchase."

Portable System Delivers the Goods

Cattleman Dale Schwiegert operated the district's portable solar system at his place near Baker, watering up to 110 cow/calf pairs on a quarter section of fall pasture. Schwiegert ran the pump 8 feet below ground surface in a 60-foot well and considered it "as reliable as any-

thing around." The unit pumped up to 5 gallons a minute on bright, sunny days. Schwiegert used a 12-volt battery as a backup power source when sunlight was not enough to pump the required amount of water.

Schwiegert mentioned the cost of solar systems as one possible disadvantage. The pump that the district lent to Schwiegert cost about $2,500, and the panels were about $400 each. Another possible disadvantage of this particular pump is that it requires a well casing at least 5 inches in diameter, larger than many existing wells.



Barry Hedrich with his solar panels, slightly bent by bulls, near Ringling

Big System Fails

Jensen, Schwiegert, and others involved with the two portable panels and the pump that went with them considered the solar pumping experiment a success. A second solar pumping project in the district was a failure, however. This was a much larger project in isolated territory west of Baker. A jack pump was installed on a 160-foot well with 24 solar panels. For unknown reasons, the panels never provided the power necessary to operate the pump. Worse yet, the manufacturer of the panels went out of business, and the panels could not be replaced under any warranty. The lesson is to stick with established suppliers of time-tested and warrantied equipment.

"Before I got this system, cattle had to walk down to the creek"

BARRY HEDRICH, RINGLING

A Completely Reliable System

On his ranch near Ringling, Barry Hedrich relies on solar power for cow water. "Before I got this system, cattle had to walk down to the creek," he said. After two years of operation, Hedrich said his system has been completely reliable except for problems caused by an air lock in the water line leading to a cistern and watering tank. "It needs to be better vented," he said. The system includes 21 solar panels, a jack pump, a 4,000-gallon cistern near the well, and a 1,500-gallon tank 1,500 feet away.

Hedrich said the system provides up to 5 gallons a minute, enough to water up to 100 cow/calf pairs. "One thing these systems need," Hedrich said, "is a supplemental or backup system." Such backup could be provided by a submersible pump and a portable generator, he said, adding that he was considering such possibilities.

Panels Not Bull Proof

Hedrich's consideration of a backup system was reinforced when some of his rambunctious bulls got too close to the panels and broke some of them. "They're not bull proof," he said.

As it is, Hedrich said, the solar system is a good thing to have. "It uses a renewable resource and works real well. I might put in another one."

ARVILLE LAMMERS, SHAWMUT

Solar Pumping Provides 40 Extra Days of Pasture

On Careless Creek near Shawmut, the Lammers family has used solar water pumping to change the grazing patterns on the family ranch. Arville Lammers said that the water provided by the system provides at least 40 extra grazing days on crested wheat spring pasture. "This gets the animals out of the riparian areas," he said, noting that, before the system was installed, drinking water for cattle and sheep was in a wet area more than a mile from the new water tanks.

50,000-Gallon Storage

The initial element of Lammers's pumping system is 75 feet of perforated 6-inch pipe laid in the gravel under Careless Creek. This pipe is connected to a 12-foot deep well where the submersible pump is installed. This pump is powered by six solar panels in a sun-tracking mount and provides up to 7 gallons per minute. Water from the pump is delivered through inch-and-a-half-pipe to a 50,000 gallon lined storage pit at an elevation about 80 feet higher than the pump and 600 feet away.

Water from the storage pit is gravity fed to a 6,000-gallon tank 3,200 feet away, and to a second tank 5,200 feet beyond the first. The water level in the tanks is controlled with a float valve system.

Arville Lammers and Cheryl Miller at Lammers' 50,000 -gallon plus storage pit near Shawmut

"The first year, I had 100 cow/calf pairs and 500 sheep in here," Lammers said, "and I had water enough for more. This year I'll have 180 pairs in there, and maybe another 110 for a little bit, and 500 sheep. We're trying to stay off our other pasture for as long as possible."

Sun More Reliable than Wind

"We've had windmills on the place since 1941, and I can tell you these solar systems are a lot more reliable," Lammers said. On the down side, the system

Roy Nollkamper with demonstration solar system near Cut Bank

has been inoperable at times because of gearbox problems with the pump. These occurred because the pump was essentially a prototype and not through the testing stage. Lammers said the manufacturer provided new gearboxes to keep him running, and he was in the process of altering the system to eliminate the problem.

GLACIER ELECTRIC COOPERATIVE, CUT BANK

Solar System Pumps 300,000 Gallons First Year

When the Sandia National Laboratory in New Mexico was looking for a place to demonstrate solar water pumping in Montana, it probably did not need to go clear to Cut Bank, but did anyway. Roy Nollkamper, Director of Member Services for the Glacier Electric Cooperative, said the cooperative also had a role in developing the demonstration project. "We are always looking for ways to encourage the use of renewable energy," Nollkamper said, "and we learned that the laboratory was offering financial assistance for such a project."

Saving Everybody Money

Unless alternative systems are used, it is usually necessary to extend electric distribution lines to run a pump. "Extending these lines costs the company, and it costs the ratepayer," Nollkamper said. "We wanted to find out if solar systems would work." Sandia wanted a demonstration in an area with good sun and no power service, Nollkamper said. The cooperative helped them find the place, some miles east of Cut Bank on the Blackfeet Indian Reservation. "With this system, he (the leaseholder) waters a hundred cow/calf pairs, up from nothing before."

On April 29, 1992, the system went into service. The pump is 88 feet down a well and provides up to 7 gallons per minute. A meter on the well shows that over 300,000 gallons were pumped in the first season. All the water is delivered to a single 250-gallon tank at the well site, but the leaseholder intends to install a 20,000-gallon storage tank in the future.

A Zero-Maintenance Outfit

"Maintenance on the system has been zero so far," Nollkamper said. "We spent the extra money to put in a high reliability system to keep maintenance down. These systems are not cheap, but they get more feasible as the

costs of extending electric service go up." Nollkamper said Glacier Electric Cooperative's fee for installing a mile of distribution line to power a pump would be about $25,000.

PHIL FOX, HYSHAM

Solar Pioneer Has 10-Year Track Record

When it comes to solar-powered water pumping in Montana, Phil Fox of the P and L ranch near Hysham began as a pioneer and has evolved with experience into an enthusiast. "I was sitting around one day fooling with my gasoline pump motors, and I said to myself, 'Why can't we use the sun to pump water?' That was in 1983.

Fox checked around and discovered a man in Billings who claimed experience at adapting pumping equipment to operate on solar power. "He got this piece from here and that piece from there and fixed me up a system that worked," he said. The pump that went with this system was a long way from the solar-powered pumps of the 1990s.

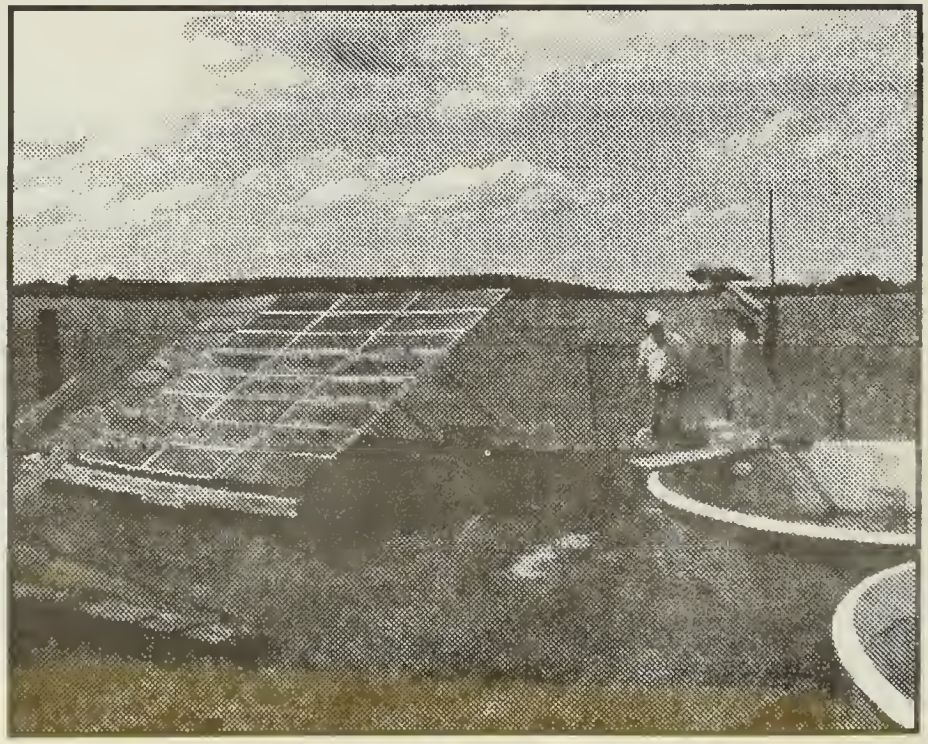
An Archimedes Screw

"It was an Archimedes screw," Fox said. The Archimedes screw has a truly impressive operating record, dating back 2,000 years to when Archimedes invented it. The modern version of the Archimedes screw developed for Fox went into service in 1983 and continues to function today, after various modifications.

When first installed, the system was powered by six solar panels on a stationary mount. Eventually the efficiency was improved with a sun-tracking mount. Two more panels were added, and then two more, up to the present total of ten. The additional panels are needed in part to charge batteries that are used to keep the pump operating at night. Night time operation was necessary to provide the daily 3,000 to 3,500 gallons of water needed to partially serve the needs of the 180 cow/calf pairs and 10 or so bulls in the three pastures served by the system. The total area of the three pastures is 4,200 acres.

Car Batteries not the Answer

The man who rigged the system hooked it up at first to regular car batteries, which lasted "about two days," Fox said. Fox replaced those batteries with heavy Caterpillar batteries, which worked for two years but were not well suited for the purpose. "What you need are deep cycle



Phil Fox with one of his solar water pumping systems near Hysham

batteries of a particular type," Fox said, noting that deep cycle batteries come in numerous varieties for various purposes. "I think the ones for golf carts are about right," he said.

A more conventional solar system was installed on the P and L Ranch in 1989. This system uses a 3/4 horsepower jack pump to lift as much as 1,800 gallons a day 250 feet up a well casing. Fox said the well for this system was drilled with the intent of installing a solar-powered pumping system. Water is pumped into two 1,000-gallon storage tanks at the well site and gravity fed to two additional 1,000-gallon watering tanks 2,000 feet away. The nearest pre-existing water in the 1,600 acre pasture is two miles from the well. Use of the system to distribute water more evenly in the pasture helps keep the pasture more evenly grazed, Fox said.

All Hail Breaks Loose

One possible problem with some older solar panels was demonstrated when several of those at this site were broken by hail. Fortunately, no cattle were in the pasture, and the system was not operating at the time. Panels being produced in 1993 have a 20-year warranty against such damage and are made of tempered glass that can withstand much more severe storms than older units.

A third solar pumping system on the P and L Ranch was installed in 1992 and functioned perfectly through its first season. "I did all the work on this one myself," Fox said. The system includes four solar panels in a sun-tracking mount and a diaphragm-type submersible pump 43 feet down a well. Production is up to 2,500 gallons of water a day. "That's enough for about 75 to 100 cows and calves a day," Fox said. Before installation of this system, no stock water was available at the site, which is in a 6,400-acre pasture. Fox said he hopes to develop two or three more tanks in widely separated areas of the pasture.

A fourth stockwatering system on the Fox ranch uses two panels to produce 500 gallons a day. Fox said he intends to add two more panels and batteries to this system to increase water production. The batteries are necessary so the low-production well can be pumped at night. Adding panels without batteries would not increase production because the well already is pumped near its production rate during the day.

Punk Luck with Propane Pumps

Fox is enthusiastic about his solar pumps. Before he had solar pumps, Fox said, he had propane-fired pumps. "I had terrible luck with the propane pumps. I'd get them running, and, as soon as I left, they'd quit. And it was always some different problem."

After the propane systems, he went to gasoline-powered systems. "They (gasoline systems) were time-consuming. You had to go out there and start them every day, and they used a gallon or two of gas every day. That adds up. I'd do about anything to keep from going back to those little gas motors."

Fox said his solar systems are generally easy to get along with and have given him some peace of mind. "Anybody who's ever gone out there and found the water tank empty and the cows standing around thirsty would be glad to have a system as reliable as these," he said.

NOTES

SOLAR